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The Ɵptimum Decisions in Improving Sustainable Road Network Infrastructure by Using ,GIS , Graph Theory and L-matrix

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ABSTRACT

Road network infrastructure is the key indicator of sustainable spatial development, as it affects the economy, environment, and society activities. These can be optimized through minimizing the time the vehicles take on the road, which in turn requires high connectivity and then high accessibility between the nodes of the road network. However, it is necessary to put a development strategy that helps the decision makers to produce relative high accessibility over the development time.

In this paper, the vulnerabilities regarding the connectivity and spatial accessibility were pinpointed and analyzed, optimum priorities in sequent new linkages adding are made for developing a sustainable infrastructure with faster enhancement for the spatial accessibility. The results have become a tough guidance for decision makers, and can be adopted as a first step for legislating a strategy for sustainable transportation system.

1. Introduction

The road network of al-Anbar governorate suffers from inadequacy infrastructure in term of availability especially the absence of the direct linkages between many pairs of the adjacent cities. This problem causes disturbances over the available links that suffer from inadequacy in their capacities, not to mention the risks resulted from the bad construction and the low-level service for them. This problem has become to be sustainable problem rather than providing transportation system to be sustainable. The essential problem is to travel over n links such that forces the passengers to travel additional distance (travel time) between an origin and a destination [1], and hence non-uniform access and services resulting in widespread negative consequences. These consequences have direct harmful effects on environment due to noise and atmospheric pollutants emitted from the road sector such as carbon monoxide emissions, impairing the economy due to travel cost, and society activities [2], [3]. In this situation, improvements of spatial accessibility are seen as a critical priority to basis for a development strategy toward a sustainable transportation system and hence minimizing the above consequences [1]. It is important to mention that the sustainability addresses economy, environment and society as major dimensions [4], that restrict the guidance principles of the approach strategies (avoid, shift, and improve) that intricately linked with develop the elements (infrastructure, modes, and operations) of any sustainable transport system to be sustainable [2], [5].

The sustainable development handling these elements one after another according to their strate-

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gies respectively. For offsetting the consequences of a network links absence in study area toward being sustainable requires adopting the strategy of avoiding as a first step [1]. Therefore, in this paper, we will be handling the sustainable development for the network infrastructure and hence a great emphasis needs to be under hand for decision makers to legislate its implementation and establish the strategies that follow it.

In this paper, we will mostly concentrate on doing offset the missed links in a priority that ensures the aimed coinciding with the faster shifting in enhancing its accessibility. This seeking in improvement is the first step toward provide an integrated mobility and accessibility to all users in a safe and environment friendly transport modes, as the main goal of the sustainable transport system [6].

2. Methodology

In this paper, the methodology has been built to satisfy the strategy of avoiding, in which we seek for avoiding the unnecessary travel and reducing the trips time. This requires developing a sustainable road network infrastructure in term of availability. So our task will catch up with examine the spatial accessibility of the road network measured by the connectivity indicator. As the connectivity refers to directness between destinations, we will handle measuring topologically in actual distance to incorporate the unequal linkage weighted by the travel time.

The depended methodology requires developing a simple valued graph for the road network infrastructure. Hence, this involves deriving the road network dataset from the satellite images, applying of Arc GIS tools for digitizing the spatial data of the road network.

Hence, a series of the valued matrices will be developed and powered based on the principles of the graph theory to evaluate, analyze, and develop the road network infrastructure based on its connectivity using accessibility indicator. We will take into account comparing among the results of the spatial accessibility with each new linkage addition, to achieve the optimum priorities for the new proposed additions such that satisfy the faster shifting toward sustainability coinciding with the developing infrastructure process.

3. The study area and the existing network

Anbar city is an Iraqi province in western Iraq. It is one of the largest provinces in Iraq, an area of about one third (1/3) of Iraq see Figure 1. With an area of 138,500 square kilometers, with a total population of 1 million and 600 thousand people.

To evaluate the existing road network in study area and examine its connectivity- topologically. A simple graph for the network has been built to generate nodes and edges using Network dataset analyst of ArcGIS 9.3 as shown in Figure2, number of nodes and links was calculated to generate connectivity indices as Alpha α, Beta β, and Gamma γ to help us in measuring the functional relevance of the exist network.

Figure 1 . Al-Anbar Governorate

tween a certain pair of nodes. The nodes reality and symbols are shown in Table2.

Table 1. Descriptive spatial values of connectivity indices

Index	Minimum	Maximum	For the exits network	Formulas Where(L= 11, V=11)	Description
Alpha	0 (no. circuits)	100(a completely interacted network)	0.067	α =(L- V+P) /(2V-5) α =(11- 11+1) /(20-5)=0.067	The network is needed for adding new linkages by 93.3% for α index to be completely interconnected.[7]
Beta	1(minimal connected network)	the greater value of β, the greater connectivity	1	β =(L/V) =11/11=1	The network is about 59.3 ways to being maximally connected. It is relative weakly connected, and there is high isolation for many cities.[7]
Gamma	1/3(spinal)	1(delta)	0.407	γ=L / L max. =L/3(V-2) γ= 11/3(11-2) =0.407	Spinal configurations (. It is relatively weakly connected) [8]

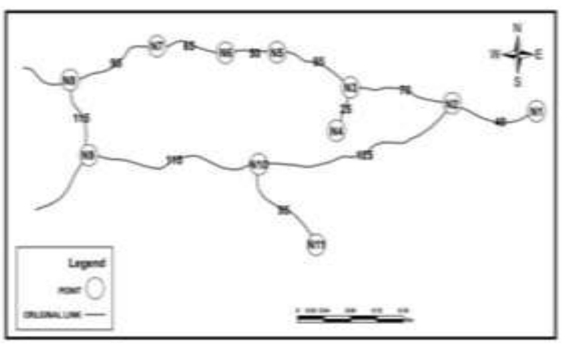

Figure 2. The digital representation for road network in term of links and nodes

Table 2. The nodes reality and symbols

No.	City in real world	Node symbole
1	Fallujah	N1
2	Ramadi	N2
3	Hit	N3
4	Kubaisa	N4
5	Haditha	N5
6	Aana	N6
7	Rawa	N7
8	Qaim	N8
9	Rutba	N9
10	Intersection	N10
11	Nikhaib	N11

These indices calculated for the network. The descriptive values of the connectivity indices shown in Table1 above:

To examine the road network connectivity, the nodal accessibility, and the overall accessibility for the network, the network simplified as a valued graph as shown in Figure 2 above. Valuing the links will be by associating them weights in order to reflect their strengths relative to one another and such record their real relevance [7],[9], hence expressing the network as a matrix and then powering a series of matrices to n matrices according the larger number of steps such that give a shortest travel time be-

Applying the graph theory techniques to the simplified weighted graph and expressing it, as matrix will enable the network not to be limited to topological properties but to give a more comparable appropriate set of values and hence discriminator tracing relevance for the associating different weighting values [8], [9]. In Table3 below each entry in the matrix represents the travel time between each two adjacent cities (direct linkage). No entry recorded between nonadjacent cities where there are no direct linkages. All the diagonal entries inserted by zeros. The powering process of matrix L1 is by multiply the matrix L1 by its self in element by element. This process will result in matrix L2, the resulted matrix L2 entries are the shortest travel time between each pair nodes that have two-step paths or two-step connected cities as shown in Table 4 below.

We will continue with matrix power procedure reaching the Ln matrix that give us shortest travel time between all pairs of nodes satisfied from one to n steps path distributed between the different nodes according to their relative locations to each other in the network.

However, the resulted matrices are shown in Tables 5, 6, 7, and 8 where each entry in the L3 matrix represents the travel time between each three and fewer steps connect, L4 matrix represents the travel time from one to four step connections and L5matrix represents the travel time from one to five-step connections.

The matrix in Table 8 is the total matrix where each entry in the matrix represents the travel time from one to six steps connections., in which each row sum means the total driving time needed to move from that node to all other nodes in the network and the minimum row sum means the most accessible node. So the node 3 is the most accessible node in the existing network, it takes 1580 minutes to move over the entire network destination. The node 3 has the minimum step weighted paths that connect it with the other nodes. The larger accessibility indicates relative higher connectivity.

Table 3. L1-Matrix for the existing network

O/D	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11
N1	0	40	0	0	0	0	0	0	0	0	0
N2	40	0	70	0	0	0	0	0	0	125	0
N3	0	70	0	25	55	0	0	0	0	0	0
N4	0	0	25	0	0	0	0	0	0	0	0
N5	0	0	55	0	0	50	0	0	0	0	0
N6	0	0	0	0	50	0	65	0	0	0	0
N7	0	0	0	0	0	65	0	95	0	0	0
N8	0	0	0	0	0	0	95	0	115	0	0
N9	0	0	0	0	0	0	0	115	0	110	0
N10	0	125	0	0	0	0	0	0	110	0	85
N11	0	0	0	0	0	0	0	0	0	85	0

Table 4. L2-Matrix for the existing network

O/D	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11
N1	0	40	110	0	0	0	0	0	0	165	0
N2	40	0	70	95	125	0	0	0	235	125	210
N3	110	70	0	25	55	105	0	0	0	195	0
N4	0	95	25	0	80	0	0	0	0	0	0
N5	0	125	55	80	0	50	115	0	0	0	0
N6	0	0	105	0	50	0	65	160	0	0	0
N7	0	0	0	0	115	65	0	95	210	0	0
N8	0	0	0	0	0	160	95	0	115	225	0
N9	0	235	0	0	0	0	210	115	0	110	195
N10	165	125	195	0	0	0	0	225	110	0	85
N11	0	210	0	0	0	0	0	0	195	85	0

Table 5. L3-Matrix for the existing network

O/D	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11
N1	0	40	110	135	165	0	0	0	275	165	250
N2	40	0	70	95	125	175	0	0	235	125	210
N3	110	70	0	25	55	105	170	0	305	195	280
N4	135	95	25	0	80	130	0	0	0	220	0
N5	165	125	55	80	0	50	115	210	0	250	0
N6	0	175	105	130	50	0	65	160	275	0	0
N7	0	0	170	0	115	65	0	95	210	320	0
N8	0	0	0	0	210	160	95	0	115	225	310
N9	275	235	305	0	0	275	210	115	0	110	195
N10	165	125	195	220	250	0	320	225	110	0	85
N11	250	210	280	0	0	0	0	310	195	85	0

Table 6. L4-Matrix for the existing network

O/D	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11
N1	0	40	110	135	165	215	0	0	275	165	250
N2	40	0	70	95	125	175	240	0	235	125	210
N3	110	70	0	25	55	105	170	265	305	195	280
N4	135	95	25	0	80	130	195	0	330	220	305
N5	165	125	55	80	0	50	115	210	325	250	335
N6	215	175	105	130	50	0	65	160	275	385	0
N7	0	240	170	195	115	65	0	95	210	320	405
N8	0	0	265	0	210	160	95	0	115	225	310
N9	275	235	305	330	325	275	210	115	0	110	195
N10	165	125	195	220	250	385	320	225	110	0	85
N11	250	210	280	305	335	0	405	310	195	85	0

Table 7. L5-Matrix for the existing network

O/D	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11
N1	0	40	110	135	165	215	280	0	275	165	250
N2	40	0	70	95	125	175	240	335	235	125	210
N3	110	70	0	25	55	105	170	265	305	195	280
N4	135	95	25	0	80	130	195	290	330	220	305
N5	165	125	55	80	0	50	115	210	325	250	335
N6	215	175	105	130	50	0	65	160	275	385	385
N7	280	240	170	195	115	65	0	95	210	320	405
N8	0	335	265	290	210	160	95	0	115	225	310
N9	275	235	305	330	325	275	210	115	0	110	195
N10	165	125	195	220	250	385	320	225	110	0	85
N11	250	210	280	305	335	385	405	310	195	85	0

Table 8. L6-Matrix for the existing network

O/D	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	Total
N1	0	40	110	135	165	215	280	375	275	165	250	2010
N2	40	0	70	95	125	175	240	335	235	125	210	1650
N3	110	70	0	25	55	105	170	265	305	195	280	1580
N4	135	95	25	0	80	130	195	290	330	220	305	1805
N5	165	125	55	80	0	50	115	210	325	250	335	1710
N6	215	175	105	130	50	0	65	160	275	385	385	1945
N7	280	240	170	195	115	65	0	95	210	320	405	2095
N8	375	335	265	290	210	160	95	0	115	225	310	2380
N9	275	235	305	330	325	275	210	115	0	110	195	2375
N10	165	125	195	220	250	385	320	225	110	0	85	2080
N11	250	210	280	305	335	385	405	310	195	85	0	2760
Total												22390

4.Road network infrastructure development

For developing the existing road network infrastructure, we proposed ten new linkages additions to be added to exists network. These additions have been selected such that establish two goals, the first is to provide direct linkage between each pair of the adjacent cities. The second is to develop the existing network performance to delta configuration that support a triangle linking for each set of three nodes in the network. Establishing these goals will result in high density linking relative to exists nodes.

The proposed linkage additions are simplified as a valued graph by ArcGIS tools to substitute the absent links and weighted by the driving time needed to travel between each pair of the adjacent cities, the valued proposed new linkages are shown in Figure3 and Table9.

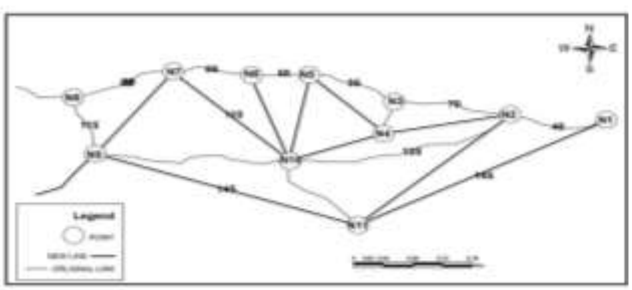

Figure 3. The new proposed additional valued links to the existing network

The effective improvement should not pass through random stages; especially the improvement financing will be annually. Therefore, it is important to achieve the new linkage additions and implement them according to tough priorities such that establish effective and relative faster shifting to sustainable infrastructure with faster enhancement in accessibility and then faster reduction in the existing negative impacts**.**

Table 9. The new proposed additional valued links to the existing network

Sequence	Proposed linkage	Driving time between the linked nodes (min)
1	N1-N11	145
2	N2-N4	65
3	N2-N11	115
4	N4 -N5	60
5	N4-N10	85
6	N5-N10	80
7	N6-N10	90
8	N7-N10	110
9	N7-N9	75
10	N9-N11	145

Applying the graph theory principles and then L-matrix possibilities on the valued graph of the network with each new linkage addition result in tough outputs, such that permit us to pinpoint a comparative accessible improvement due to the ten proposed additions. These comparative values will be in term of minimizing the overall travel time over the network paths.

The L-matrices for competitive new proposed linkages to be the first new addition to the existing network have been achieved by the same process in representation and analysis. The powering process illustrated for obtaining the comparative accessibility for the proposed new addition N1-N11 in Tables 10, 11, 12, 13, 14, 15. In Table 10 below L1-matrix for calculating the overall network accessibility with the proposition 1 (N1-N11) as a new linkage for choosing the first new linkage addition among the other propositions.

Table 10. L1-Matrix for the network with the proposition 1 (N1-N11).

O/D	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11
N1	0	40	0	0	0	0	0	0	0	0	145
N2	40	0	70	0	0	0	0	0	0	125	0
N3	0	70	0	25	55	0	0	0	0	0	0
N4	0	0	25	0	0	0	0	0	0	0	0
N5	0	0	55	0	0	50	0	0	0	0	0
N6	0	0	0	0	50	0	65	0	0	0	0
N7	0	0	0	0	0	65	0	95	0	0	0
N8	0	0	0	0	0	0	95	0	115	0	0
N9	0	0	0	0	0	0	0	115	0	110	0
N10	0	125	0	0	0	0	0	0	110	0	85
N11	145	0	0	0	0	0	0	0	0	85	0

Table 11. L2-Matrix for the network with the proposition 1 (N1-N11).

O/D	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11
N1	0	40	110	0	0	0	0	0	0	165	145
N2	40	0	70	95	125	0	0	0	235	125	185
N3	110	70	0	25	55	105	0	0	0	195	0
N4	0	95	25	0	80	0	0	0	0	0	0
N5	0	125	55	80	0	50	115	0	0	0	0
N6	0	0	105	0	50	0	65	160	0	0	0
N7	0	0	0	0	115	65	0	95	210	0	0
N8	0	0	0	0	0	160	95	0	115	225	0
N9	0	235	0	0	0	0	210	115	0	110	195
N10	165	125	195	0	0	0	0	225	110	0	85
N11	145	185	0	0	0	0	0	0	195	85	0

However, each new priority in next additions will take in consideration reducing the number of the competitive new proposed additions by the number of the previous decided priorities. With each new linkage addition, we apply the same scenario of L-matrix powering for the new existing network resulted with the last previous additions. However, the L-matrices for all the proposed additions take the same process o analyzing, the priorities in addition all the propositions, the comparative minimizing in overall travel time and the percent enhancement in overall accessibility shown in Table 16.

Table 12. L3-Matrix for the network with the proposition 1 (N1-N11).

O/D	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11
N1	0	40	110	135	165	0	0	0	275	165	145
N2	40	0	70	95	125	175	0	0	235	125	185
N3	110	70	0	25	55	105	170	0	305	195	255
N4	135	95	25	0	80	130	0	0	0	220	0
N5	165	125	55	80	0	50	115	210	0	250	0
N6	0	175	105	130	50	0	65	160	275	0	0
N7	0	0	170	0	115	65	0	95	210	320	0
N8	0	0	0	0	210	160	95	0	115	225	310
N9	275	235	305	0	0	275	210	115	0	110	195
N10	165	125	195	220	250	0	320	225	110	0	85
N11	145	185	255	0	0	0	0	310	195	85	0

Table 13. L4-Matrix for the network with the proposition 1 (N1-N11).

O/D	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11
N1	0	40	110	135	165	215	0	0	275	165	145
N2	40	0	70	95	125	175	240	0	235	125	185
N3	110	70	0	25	55	105	170	265	305	195	255
N4	135	95	25	0	80	130	195	0	330	220	280
N5	165	125	55	80	0	50	115	210	325	250	310
N6	215	175	105	130	50	0	65	160	275	300	0
N7	0	240	170	195	115	65	0	95	210	320	405
N8	0	0	265	0	210	160	95	0	115	225	310
N9	275	235	305	330	325	275	210	115	0	110	195
N10	165	125	195	220	250	300	320	225	110	0	85
N11	145	185	255	280	310	0	405	310	195	85	0

Table 14. L5-Matrix for the network with the proposition 1 (N1-N11).

O/D	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11
N1	0	40	110	135	165	215	280	0	275	165	145
N2	40	0	70	95	125	175	240	335	235	125	185
N3	110	70	0	25	55	105	170	265	305	195	255
N4	135	95	25	0	80	130	195	290	330	220	280
N5	165	125	55	80	0	50	115	210	325	250	310
N6	215	175	105	130	50	0	65	160	275	300	385
N7	280	240	170	195	115	65	0	95	210	320	405
N8	0	335	265	290	210	160	95	0	115	225	310
N9	275	235	305	330	325	275	210	115	0	110	195
N10	165	125	195	220	250	300	320	225	110	0	85
N11	145	185	255	280	310	385	405	310	195	85	0

Table 15. L6-Matrix for the network with the proposition 1 (N1-N11).

O/D	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	Total
N1	0	40	110	135	165	215	280	375	275	165	145	1905
N2	40	0	70	95	125	175	240	335	235	125	185	1625
N3	110	70	0	25	55	105	170	265	305	195	255	1555
N4	135	95	25	0	80	130	195	290	330	220	280	1780
N5	165	125	55	80	0	50	115	210	325	250	310	1685
N6	215	175	105	130	50	0	65	160	275	300	385	1860
N7	280	240	170	195	115	65	0	95	210	320	405	2095
N8	375	335	265	290	210	160	95	0	115	225	310	2380
N9	275	235	305	330	325	275	210	115	0	110	195	2375
N10	165	125	195	220	250	300	320	225	110	0	85	1995
N11	145	185	255	280	310	385	405	310	195	85	0	2555
												21810

5. Results

The outlined results for the connectivity indices (α, β, and γ) of exist road network illustrated in Table 1, referred to a configuration weakly connected, and it is need for 59 new linkages to be maximally connected network. However, the evaluation results indicate an irreparable harm to future generations due to a wide range of the negative impacts related the deplorable road network. From the evaluation results and tracing the topological characteristics and the road network configuration. We find that the missed linkages in exist infrestructure restrict the

Table 16. The priorities in adding the new proposed linkages and the enhancement percent.

The new addition no.	Minimizing in overall travel time (min) (accessibility increment)	Percent enhancement
1	3145	14%
2	2268	10.13%
3	2192	9.8%
4	1928	8.61%
5	1622	7.25%
6	1318	5.88%
7	911	4.07%
8	625	2.79%
9	452	2.02%
10	213	0.95%
Total reduction		65.5%

trips in a unique path through Unintended cities, which had becoming congesteddue to the fact that full capacity of exist roads inside these cities was especially during peak travel periods [10] [6].

However, regardless the delay due to absence of the direct linkages, there is an impedance to travel result in increased the travel time. Which in turn contribute with the long path to generate many risks to the society, economy and the environment, to the high negative environmental and economic impacts especially that all the used modes to travel are motorized.

Generally speaking, the absent direct linkages, the non-constant long travel time, and then the resulted risks, reflect the big gap between the supply and demand in study area [11].

In this paper, we seek to not only reduction the risks, but to put the first step toward reach the inclusive sustainability in transportation to save public health, environment, and economic benefits are topics that deserve attention [12].

network toward improvement. It is assumed that the decision makers will have an inductive role in reality of the road network is deteriorating, and took it seriously and appreciated their responsible attitude to a handful of carefully selected scenarios in the near future [15]

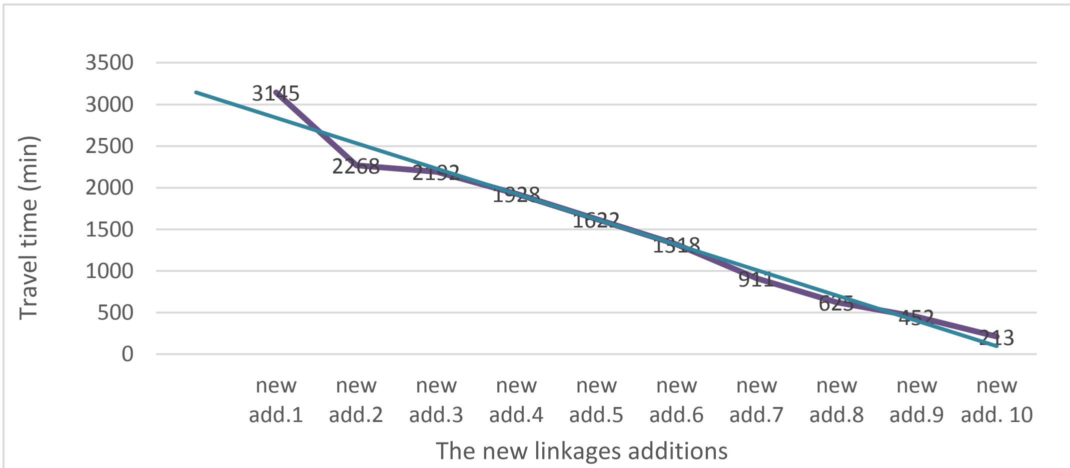

Figure 4. The overall travel time reduction with each new linkage addition.

After an inductive evaluation for real world of the infrastructure and the investigated weakness due to the lack in availability of direct linkages between several nodes of the network, a stipulation of appropriate infrastructure has become urgent and ongoing requirement [13]. This paper outlined an effective solution for improving the road network infrastructure and reducing its negative impacts toward sustainability.

The results in Figure 4 ensure high travel time reliability that the travel between each pair of the adjacent cities can be accord successfully within a certain time [14].

However, Economies that possess greater connectivity is often that with better opportunities for developing than that with scarce connectivity, where a lack of access impedes and restricts development while greater access is a catalyst for development.

Any new linkages availability between the adjacent cities will provide the suitable alternative paths, which in turn contribute to divert the traffic for spilling over them.this in turn, increase the attractiveness and contribute significantly to lower dependence on private cars, and support the use of public transport especially for daily commute and the calculated accessibility measure with each new linkage addition was a good discriminator for selection the priorities of the new additions in implementation process, such that coinciding with faster shifting in reduction the negative consequences of exist

They should work to ensure infrastructure availability to basis for sustainable transportation.

The Table 16 and the Figure 4 shows the volume of the positive results to our problem solution toward development such that it can be argued that the decision makers have a well-built infrastructure network that satisfies the first step and the prerequisite of the sustainable development in transportation sector [15].

However, the results indicate a clear guidance that the decision makers now are capable of effectively legislating a project to bridge the gap in the exist system as a first step of transport sustainability and give its practical relevance.

The accessibility and connectivity measures that have been resulted from the new linkage additions are a clear guidance for decision makers to trace the faster changes toward the first approach (infrastructure availability) of sustainable mobility.

6. Conclusion:

The problems of al-anbar transport system can be eliminated in its configuration and infrastructure due to lack in links availability between many adjacent cities. It will, however, take time, money, and a combined effort on the part of many related governmental offices and decision makers. The paper results provide a guideline for decision makers to trace the optimum priorities for improving the road network infrastructure in such a way that satisfy the faster shifting towards maximally connected network with high accessibility coinciding with sustainability requirements. The priorities have been built based on the principles of Arc GIS, graph theory, and L-matrix requirements and then outlined in tough and accurate results. If these priorities can be implemented, we will surely see a decrease in travel time and then safer and sustainable environment of mobility for users, neighborhoods for all, and channelizing the annual financing. On the other hand, as the infrastructure availability is considered as the principle of avoiding which represents the first of the sustainability elements, this paper solving the grand percent of the network system problem, and basis to applying the two other elements of sustainability (shifting the mode and improving the operation).

7. Recommendations

Based on what the community suffers and the environment and the economy are affected by the deteriorating reality of the road network in the study area. It is time for decision-makers to shoulder their responsibilities to protect the environment and wealth of future generations through the construction of a sustainable transportation system depend the important causes and the solutions given in the theoretical evidence provided by this study, and therefore recommend the following:

1- Based on what the community suffers and the environment and the economy are affected by the deteriorating reality of the road network in the study area. It is time for decision-makers to shoulder their responsibilities to protect the environment and wealth of future generations through the construction of a sustainable transportation system depend the important causes and the solutions given in the theoretical evidence provided by this study, and therefore recommend the following:

2- Should play a core role from the decision makers for financing the project of this step of the sustainable transport, and seek for moving sustainable transportation financing forward to reach a conclusive sustainability handling all its approaches (availability, shifting, and improve).

3- Supporting efforts and experience to upgrade studies regarding the other approaches.

4- Applying the investments in transportation sector coinciding with the annual governmental financing to promote reaching the sustainable mobility, especially in shifting and improvement approaches.

References

[1] J.Bengtsson, B. Tómasson, "Vulnerability and risk analysis of the road infrastructure in Reykjavík Áhættu- og áfallaþolsgreining vegakerfsins í Reykjavík," no. March, 2008.

[2] J. P. Rodrigue. " The Geography of Transport Systems". Fourth Edition, New York: Routledge. ISBN 978-1138669574; P 17-28. 2017.

[3] M. O 'mahony, B. Broderick, L. Gill, A. Ahern, and L. English, "*Scope of Transport Impacts on the Environment*" *(2000-DS-4-M2)*. 2002.

[4] S. Rajak, P. Parthiban, and R. Dhanalakshmi, "Sustainable transportation systems performance evaluation using fuzzy logic," *Ecol. Indic.*, vol. 71, pp. 503–513, 2016.

[5] UNESCAP, "Concept of Sustainable Transport: Planning and Designing for Sustainable and Inclusive Transportation Systems National Capacity Building Workshop on Sustainable and Inclusive Transport Development," no. July, 2015.

[6] I. Makarova, K. Shubenkova, and L. Gabsalikhova, "Analysis of the City Transport System'S Development Strategy Design Principles with Account of Risks and Specific Features of Spatial Development," *Transp. Probl.*, vol. 12, no. 1, pp. 125–138, 2017.

[7] M. E. J. Newman, "Analysis of weighted networks," *Phys. Rev. E - Stat. Physics, Plasmas, Fluids, Relat. Interdiscip. Top.*, vol. 70, no. 5, p. 16, 2004.

[8] E. J. Taaffe, h. l. Gauthier, and M. E. O'kelly, "*Geography of transportation*", P. 18-21,1996.

[9] R. C. Thomson and D. E. Richardson, "A graph theory approach to road network generalisation," *Proceeding 17th Int. …*, pp. 1871–1880, 1995.

[10] O. Ogunleye, A. Ajibola, O. Enilolobo, and O. Shogunle, "Influence of road transport infrastructure on agricultural sector development in Nigeria," *Logist. Sustain. Transp.*, vol. 9, no. 1, pp. 39–45, 2018.

[11] A. Mahendra, M. Raifman, and H. Dalkmann, "Financing Needs for Sustainable Transport Systems for the 21st Century," 2013.

[12] F. Xie and D. Levinson, "Measuring the structure of road networks," *Geogr. Anal.*, vol. 39, no. 3, pp. 336–356, 2007.

[13] Kristan W. "The Role of Infrastructure in a Sustainable Society", *Green Business Journal*; 2013.

[14] M. G. Sreelekha, K. Krishnamurthy, and M. V. L. R. Anjaneyulu, "Interaction between Road Network Connectivity and Spatial Pattern," *Procedia Technol.*, vol. 24, pp. 131–139, 2016

[15] V. Botrić ,J. Šišinački, and L. Škuflić. "Road infrastructure and regional development: some evidence from Croatia", Proccedings from the 46th Congress of the European Regional Science Association Enlargement, Southern Europe and the Mediterranean, Volos: University of Thessaly. 2006.